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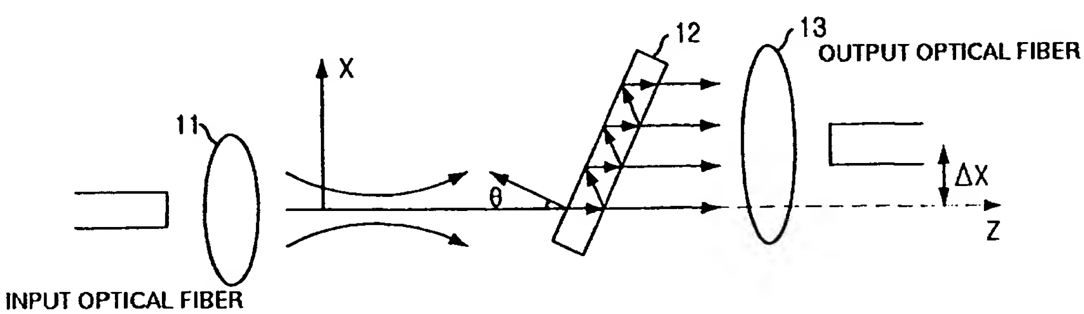

(57) Abstract

A bandwidth-variable optical filter is disclosed. The bandwidth-variable filter can continuously change a bandwidth of a transmission signal at any peak wavelength by providing vertical offsets with output signals of a Fabry-Pérot filter which controls launch angle. The bandwidth-variable filter comprises: a converter for converting a wavelength division multiplexed signal inputted through an optical fiber to a horizontal optical signal; a filter located as to rotate and have a slope, for filtering the wavelength division multiplexed horizontal signal; and a unit located vertically to a processing direction of the optical signal, for focusing transmission beam on the optical fiber in an output terminal.

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INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

IPC7 G02B 6/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimun documentation searched (classification system followed by classification symbols)

IPC7 G02B 5/28

Documentation searched other than minimun documentation to the extent that such documents are included in the fileds searched

Korean Patents and applications for inventions since 1975

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search trerms used)

IEL (optic*, filter*, bandwidth, convert*, rotat*, transmission*, collimat*, rotat*, variable*, WDM, Fabry-Perot, Lorentzian, Gaussian)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5506920 A (NEC Co.) 9 APRIL 1996 see the whole document	1
Y	US 4448486 A (David W. Evans) 15 MAY 1984 see the whole document	1-3
A	I.T.Monroy ET AL. 'Bit error evaluation of optically preamplified direct detection receivers with Fabry-Perot optical filters':IEEE JOURNAL OF LIGHTWAVE TECHNOLOGY, Vol.15, No.8, AUGUST 1997 see the whole document	4

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5506920 A	9.04.96	EP 608900 A JP 6281813 A	03.08.94 07.10.94
US 4448486 A	15.05.84	NONE	

BANDWIDTH-VARIABLE OPTICAL FILTER

Technical Field

The present invention relates, in general, to optical filters and, more particularly, to a bandwidth-variable optical filter that is capable of varying a transmission bandwidth continuously at any desired center wavelength by applying to the output light of a FP etalon, in which its light incidence angle can be adjusted, an offset in the direction perpendicular to the output light.

Background Art

In addition, the present invention relates to an optical filter, which has a superior crosstalk characteristic because it can vary the shape of a transmission spectrum so as to obtain a Gaussian transmission characteristic.

In optical Wavelength-Division Multiplexed (WDM) communication systems, Fabry-Perot (FP) filters have been widely employed for allocating and monitoring WDM channels. However, since the transmission characteristic of such a conventional FP filter has a Lorentzian transmission curve that decreases very slowly, its channel crosstalk is large and its bandwidth is fixed.

Bandwidth-variable optical filters are widely employed for the purpose of reducing channel crosstalk and Amplified Spontaneous Emission (ASE). Recently, there is proposed an angle-turned FP filter that can vary its optical bandwidth in a discrete way at a given center wavelength. The proposed FP filter can vary a channel bandwidth using the angular spread of an obliquely incident Gaussian beam, but cannot vary optical bandwidth continuously at any desirable center wavelength because a center wavelength as well as a wavelength is varied when its incident angle is adjusted.

Disclosure of the Invention

Accordingly, the present invention has been made keeping in mind the above problems occurring in the prior art, and an object of the present invention is to provide a bandwidth-variable optical filter that is capable of varying a transmission bandwidth continuously at any desired center wavelength by applying to the output light of a FP etalon, in which its light incidence angle can be adjusted, an offset in the direction perpendicular to an output light.

In order to accomplish the above object, the present invention provides a bandwidth-variable optical filter, comprising means for converting wavelength-division multiplexed incident light transmitted via an input optical fiber into parallel light, the light converting means being mounted to be rotatable so as to have its tilt angle, means for filtering the converted light by means of transmission or reflection of the light, and means for converging the filtered light having passed through the light filtering means to an output optical fiber, the light converging means being mounted to be movable in a direction perpendicular to a progress direction of the light.

In accordance with the present invention, an optical signal having passed through an FP etalon whose incidence angle is adjustable is converged via a lens that is mounted to be movable in a x-direction perpendicular to the progress direction of the optical signal, thereby varying a transmission bandwidth continuously at any desired center wavelength and allowing a transmission spectrum to have a Gaussian characteristic, and, consequently, reducing the crosstalk between channels in WDM optical communication system.

Brief Description of the Drawings

The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic diagram showing the construction of a bandwidth-

variable optical filter in accordance with the present invention;

Fig. 2 is a schematic diagram showing an arrangement for testing the characteristics of the bandwidth-variable optical filter of the present invention; and

Figs. 3a to 3f are graphs showing test results.

Best Mode for Carrying Out the Invention

A preferred embodiment of the present invention is described with reference to the accompanying drawings, hereinafter.

Fig.1 is a view showing the construction of a bandwidth-variable optical filter in accordance with the present invention. In this drawing, reference numerals 11, 12 and 13 respectively designate a first lens, a FP etalon and a second lens.

The bandwidth-variable optical filter of the present invention comprises the first lens 11 for converting incident light transmitted via an input optical fiber to parallel light, the FP etalon 12 for transmitting or reflecting the optical signal having passed through the first lens 11 depending on its wavelength, and the second lens 13 mounted to be movable in the direction perpendicular to the progress of the light for converging the light having passed through the FP etalon 12 to an output optical fiber.

The operation of the bandwidth-variable optical filter of the present invention is as follows.

Incident light reaches the first lens11 via the input optical fiber and, thereafter, is converted to parallel light in the process of passing through the first lens 11. The FP etalon 12 is formed by coating a dielectric mirror on both surfaces of a fused silica base plate that has a certain refractive index, is transparent, flat and of a uniform thickness. The FP etalon 12 is rotatably mounted so as to have a light incidence angle, that is to say, so as to adjust the incidence angle of light. A technique for rotatably mounting the FP etalon 12 so as to adjust the light incidence angle is well known, and so an explanation of this

technique is omitted in this specification.

Parallel light that has passed through the first lens 11 reaches the FP etalon 12 at an incidence angle of 2. This WDM parallel light is converted by the FP etalon 12 to multiple optical signals that respectively have certain channel bandwidths.

In the bandwidth-variable optical filter of the present invention, the second lens 13, which is positioned behind the FP etalon 12, exists on a z-axis if the progress direction of the incident light is designated as the z-axis, and converges the optical signal, which has passed through the FP etalon 12, to the output optical fiber. In the prior art, even when the FP filter is rotated, the position of the second lens is fixed.

In the bandwidth-variable optical filter of the present invention, the second lens 13 is given varied offsets in the direction of the x-axis that is perpendicular to the progress direction of the incident light and the rotational axis of the FP etalon 12, thereby allowing the transmission bandwidth to be continuously varied while the center transmission wavelength of an entire filter is kept constant. That is, in the present invention, the second lens 13 is mounted to be movable in the direction of the x-axis. Since a technique for mounting the second lens 13 to be movable in the direction of the x-axis is well known, and so an explanation of this technique is omitted in this specification.

Incidentally, besides these elements, the bandwidth-variable optical filter of the present invention further comprises a plurality of lenses that are positioned behind the FP etalon 12, and serves to converge transmitted light. When the bandwidth-variable optical filter of the present invention further comprises these lenses, this bandwidth-variable optical filter can converge effectively the optical signal that has passed through the FP etalon 12, so that the performance of the bandwidth-variable optical filter is improved still more.

The direction of the x-axis is perpendicular to the progress direction of the incident light and the rotational axis of the FP etalon 13. When)x, or an offset in the direction of the x-axis is varied, the transmission bandwidth and shape of the

transmission spectrum can be rendered to be varied within a certain range while the center transmission wavelength is hardly varied. The reason is because the incident light close to the center transmission wavelength experiences multiple reflections in the FP etalon 12 for a long time and, consequently, its transmission wave is widely distributed in the direction of x > 0 if the tilt angel 2 of the FP etalon 12 fulfills a condition of 2 > 0. Therefore, when 2 > 0 and)x is increased from 0, the wavelengths remote from the center transmission wavelength are not detected, and so the transmission spectrum assumes a periodic Gaussian curve. On the other hand, when)x is in the vicinity of 0 or less than 0, the transmission spectrum becomes similar to the original, periodic Lorentzian curve. Since the Gaussian curve is abruptly decreased in size as it gets away from the center transmission wavelength, it can be employed in the manufacture of optical filters.

Fig. 2 is a schematic view showing an arrangement for testing the characteristics of the bandwidth-variable optical filter.

As a high power broadband light source, there is used ASE of 5.8 dBm that is outputted from a first Erbium-Doped Fiber Amplifier (EDFA) 21. The ASE issued from the first Fiber Pigtailed Collimator (FPC) 22 is combined in free space and passes through the bandwidth-variable optical filter 23. Thereafter, the optical signal having passed through the bandwidth-variable optical filter 23 is recombined by means of a second FPC 24. The output spectrum of the optical signal, which is recombined by means of the second FPC 24, is measured using an optical spectrum analyzer 25. In such a case, the diameter of the incident beam is 450 μm. The shape of the transmission spectrum can be varied by adjusting the incidence angel 2 of the beam and the offset)x in the direction of the x-axis. The FP etalon 12 is made of fused silica having a refractive index of about 1.44. The mirror reflectivity of both surfaces and the thickness of the FP etalon 12 respectively are about 0.95 and about 150 μm.

The output spectra obtained while the tilt angle 2 is varied in a state where)x = 0 are illustrated in Fig. 3a. The center wavelength of a transmission peak 8_p is about 1548.6 nm, and the bandwidth is varied discretely from 0.18 nm to 1.28

nm. When)x is varied within a range of ± 300 ㎛, the center wavelength is not varied abruptly, but the bandwidth is varied continuously as shown in Fig. 3b. In a case where 2 > 0, the test result shows that the bandwidth of the output transmission spectrum is varied by wavelength-dependent multiple reflections occurring in the FP etalon 12. Behind the FP etalon 12, when the wavelength gets close to 8_p, the intensive peak of the spectrum is widely distributed toward the positive direction of the x-axis. Therefore, the transmission bandwidth is decreased along the positive direction of the x-axis but increased along the negative direction of the x-axis. This coincides with the results obtained in experiments. Therefore, as)x is larger than 0, the spectrum bandwidth of the ASE that is transmitted by the etalon filter is decreased. The intensity peak is hardly affected by)x. On the other hand, as)x is smaller than 0, the spectrum bandwidth of the ASE is increased. However, in the vicinity of an area where)x = 0 and which deviates from the distribution area of the incident beam, loss is increased largely.

In the graph of Fig. 3a, ▯ designates the output spectrum in a case where 2 = 0°, ∗ designates the output spectrum in a case where 2 = 6.9°, △ designates the output spectrum in a case where 2 = 9.9°, ◇ designates the output spectrum in a case where 2 = 15.2°, ▽ designates the output spectrum in a case where 2 = 18.9°, × designates the output spectrum in a case where 2 = 23.4°, and 0 designates the output spectrum in a case where 2 = 32°.

In the graph of Fig. 3b, ■ designates the bandwidth in a case where 2 = 0°, ● designates the bandwidth in a case where 2 = 6.9°, ∗ designates the bandwidth in a case where 2 = 9.9°, ▲ designates the bandwidth in a case where 2 = 15.2°, × designates the bandwidth in a case where 2 = 18.9°, ▼ designates the bandwidth in a case where 2 = 23.4°, and ◆ designates the bandwidth in a case where 2 = 32°.

Fig. 3c illustrates transmission spectra while the FP etalon 12 is moved in a state where 2 = 6.9°.

When the FP etalon 12 is moved in a positive direction of the x-axis, the

components whose wavelengths are close to 8_p are predominant. Therefore, when)x > 0, it can be known that the bandwidth-variable optical filter of the present invention shows a Gaussian spectrum characteristic differently from a conventional FP filter.

In the graph of Fig. 3c, □ designates the output spectrum in a case where)x = 0 µm, * designates the output spectrum in a case where)x = +300 µm, ▲ designates the output spectrum in a case where)x = +200 µm, ◇ designates the output spectrum in a case where)x = +100 µm, ▼ designates the output spectrum in a case where)x = −100 µm, 0 designates the output spectrum in a case where)x = −200 µm, and + designates the output spectrum in a case where)x = −300 µm.

Fig. 3d shows insertion losses measured with regard to the variations of 2 and)x. When there is no FP etalon, the insertion loss is 0.65 dB. When)x < −200 µm, the insertion losses are increased. However, in a case where)x > 0, or the conversion into a Gaussian characteristic in transmission characteristic occurs, the insertion losses are hardly decreased.

In the graph of Fig. 3d, ■ designates the attenuation in a case where 2 = 0°, ● designates the attenuation in a case where 2 = 6.9°, * designates the attenuation in a case where 2 = 9.9°, ▲ designates the attenuation in a case where 2 = 15.2°, × designates the attenuation in a case where 2 = 18.9°, ▼ designates the attenuation in a case where 2 = 23.4°, and ◆ designates the attenuation in a case where 2 = 32°.

Fig. 3e and Fig. 3f respectively show the output spectra in cases where)x = 0 and +300 µm when 2 = 6.9°.

Industrial Applicability

As described above, the present invention provides a bandwidth-variable optical filter, which is capable of varying a transmission bandwidth continuously at any desired center wavelength and allowing transmission spectrum to have a Gaussian characteristic by applying an offset to the output of an FP etalon, thereby

reducing the crosstalk between channels in WDM optical communication system. Additionally, the bandwidth-variable optical filter can be employed in the manufacture of Gaussian optical filters that respectively have narrow bandwidths. Since the bandwidth-variable optical filter has a variable bandwidth, it can be used for experimentally finding out the value of an optimum optical bandwidth in general optical experiments.

Claims:

1. A bandwidth-variable optical filter, comprising:

means for converting wavelength-division multiplexed incident light transmitted via an input optical fiber into parallel light, said light converting means being mounted to be rotatable so as to have its tilt angle;

means for filtering the converted light by means of transmission or reflection of the light; and

means for converging the filtered light having passed through said light filtering means to an output optical fiber, said light converging means being mounted to be movable in a direction perpendicular to a progress direction of the light.

2. The filter according to claim 1, wherein said light converging means includes one or more lenses.

3. The filter according to claim 1 or 2, wherein said light filtering means includes a rotatably mounted Fabry-Perot etalon.

4. The filter according to claim 3, wherein said Fabry-Perot etalon is mounted to adjust its tilt angle and said light converging means is mounted to adjust its offset in the perpendicular direction, so that a transmission spectrum bandwidth of the light may be varied continuously and a shape of the transmission spectrum of the light may be varied between a Lorentzian curve and a Gaussian curve.

Fig.1

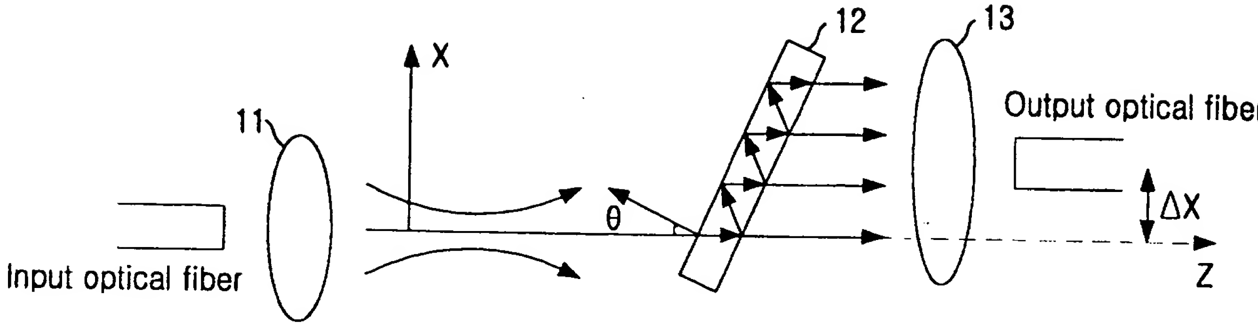

12
13
X
11
Output optical fiber
θ
ΔX
Input optical fiber
Z

Fig.2

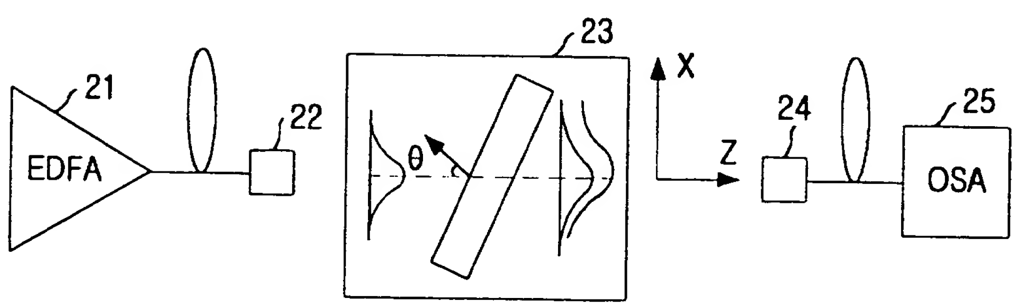

23
X
21
22
24
25
EDFA
θ
Z
OSA

Fig.3a

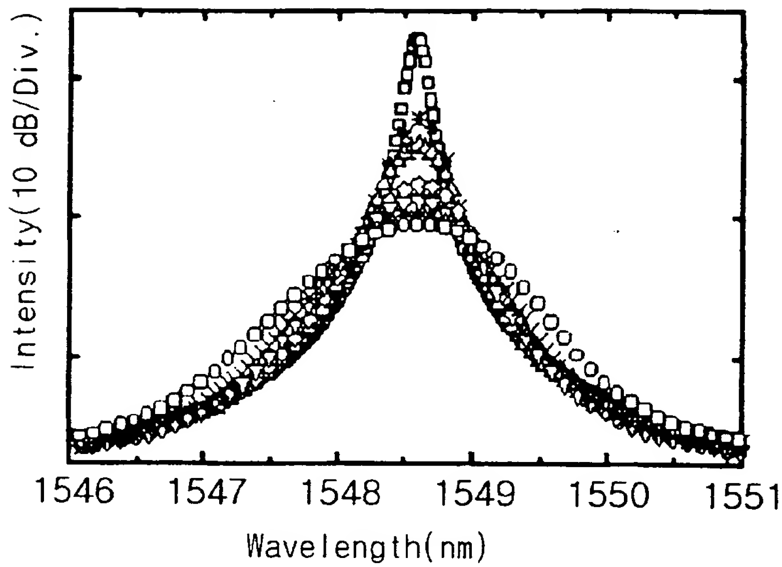

Intensity(10 dB/Div.)
1546
1547
1548
1549
1550
1551
Wavelength(nm)

Fig.3b

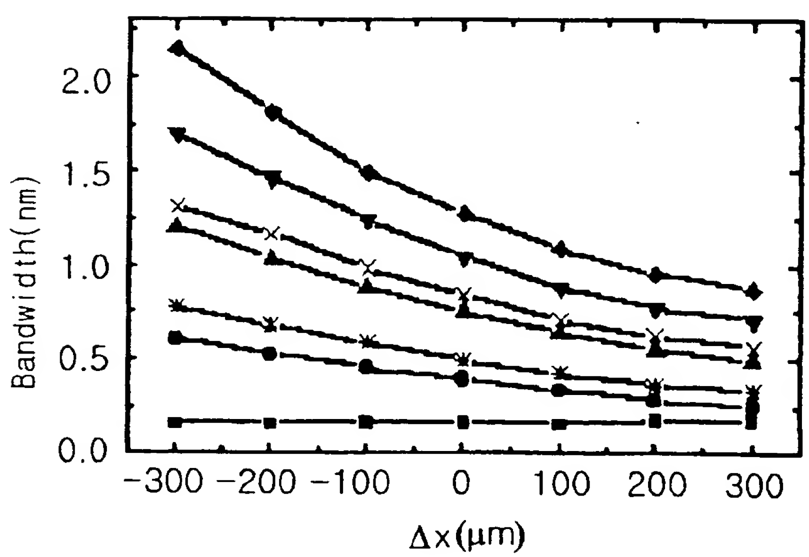

Bandwidth(nm)
2.0
1.5
1.0
0.5
0.0
−300
−200
−100
0
100
200
300
Δx(μm)

Fig.3c

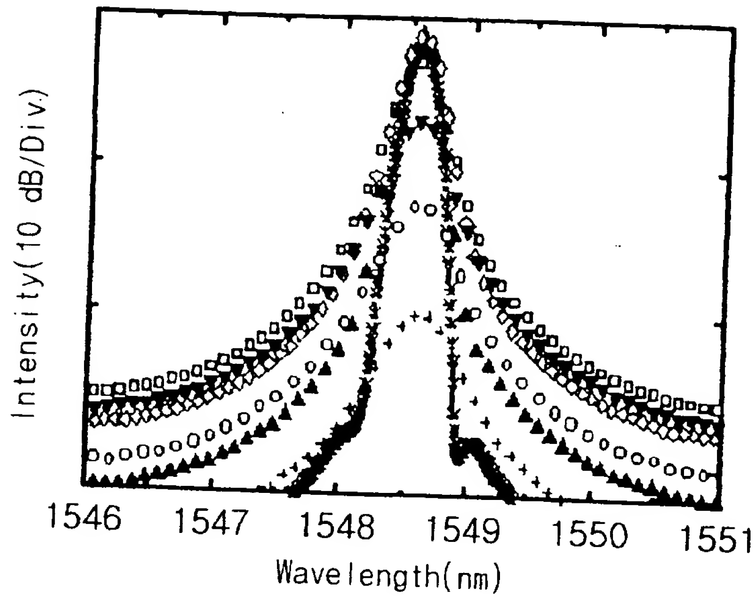

Intensity(10 dB/Div.)
1546
1547
1548
1549
1550
1551
Wavelength(nm)

Fig.3d

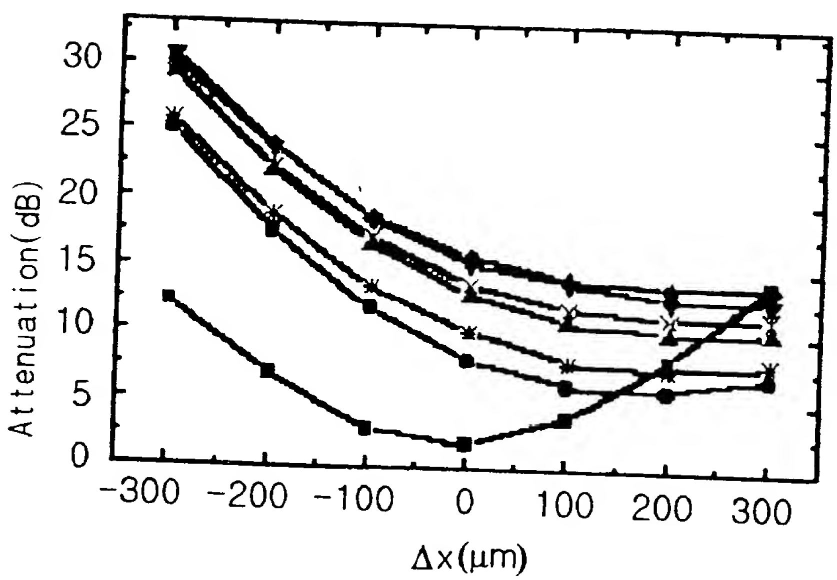

30
25
20
15
10
5
0
Attenuation(dB)
-300
-200
-100
0
100
200
300
Δx(μm)

Fig.3e

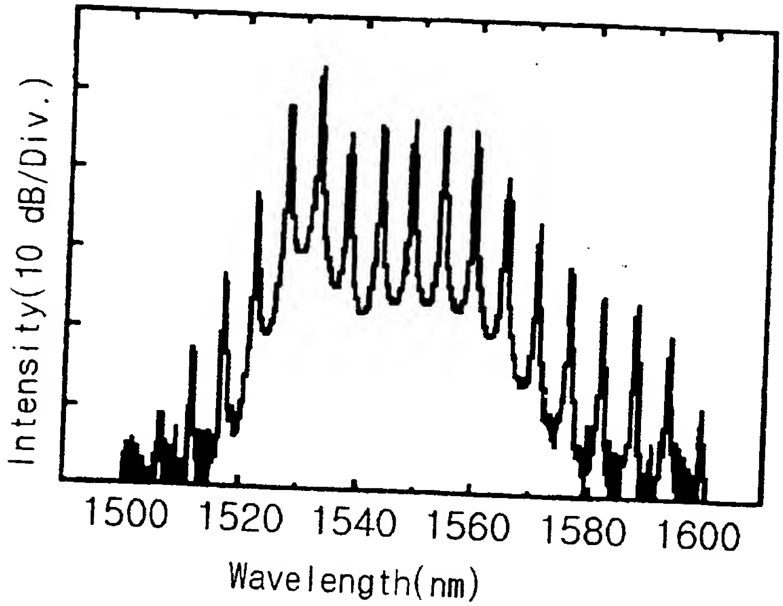
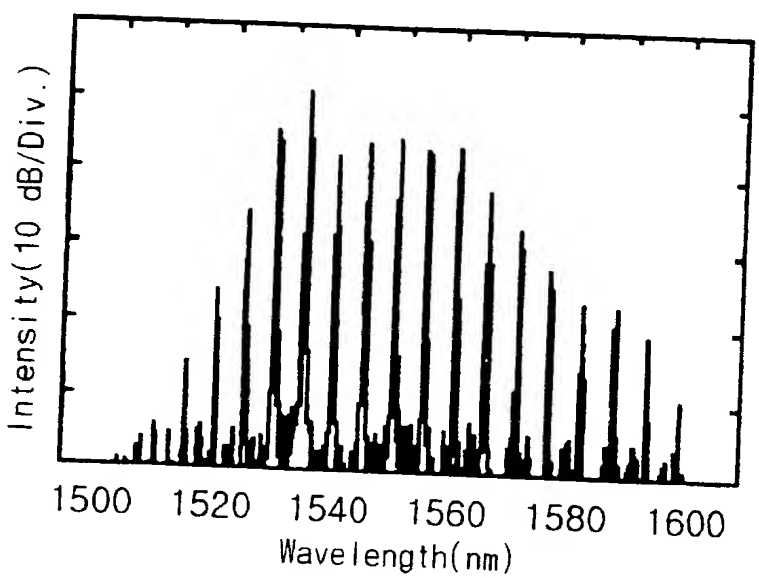

Intensity(10 dB/Div.)
1500 1520 1540 1560 1580 1600
Wavelength(nm)

Fig.3f


Intensity(10 dB/Div.)
1500 1520 1540 1560 1580 1600
Wavelength(nm)